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Discussions

Interactive comment on "A global-scale two-layer transient groundwater model: development and application to groundwater depletion" *by* Inge E. M. de Graaf et al.

Anonymous Referee #2

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Page 1. Line 1. This sentence appears to be the justification for building a global groundwater model, but this sentence is misleading. If by basins they mean surface-water basins, then lateral flow is only significant in the most surficial part of the system where >90% of the flow occurs. Most substantial groundwater withdrawals are from deeper confined and semi-confined aquifers where the total natural flow in the system is very small compared to the recharge, for example. It is true that most hydrological models do not include a groundwater flow component, but that in itself does not justify building a global groundwater model. Basically as the saying goes, "all models are wrong, but some are more useful than others"–so the authors have to demonstrate that their model is both accurate "enough" and "useful" to some degree. Unfortunately

I don't believe this model is either. It is only in the ballpark where the data exist in the 10% of the world where most of the pumping is occurring (it does a very bad job in much of the world in simply fitting depth to the water table), and it really isn't useful in the 10% of the world where the pumping is occurring because global groundwater depletion has already been quantified to a similar degree of accuracy (Wada et al, 2010, 2012; Konikow, 2011), and the groundwater model they are constructing really doesn't improve on those estimates. Lately it seems to be that the bigger the model is, the better it must be and the more likely we are to learn something new from it. Therefore the authors are now producing a global model; but in this case the model does not produce any useful results. More on this later. Page 1, line 19. This has been known for decades-why cite a reference from 2016? Why not a UN report from the 20th century? Page 2, line 29. Here the problem begins. Indeed most abstractions occur in confined aquifers (which is why the investigators include a second layer to represent them), but simulating head declines there does NOT improve any estimates of groundwater depletion. Most all groundwater depletion in deep aquifers comes out of storage, not from bounding surface-water bodies, and therefore the model -simulated depletions only mimic the abstractions that are put into the model a priori. Thus the model is only as good as the estimate of water abstractions that are available. The earlier global depletion studies did their best to estimate these abstractions. Putting these numbers into a groundwater model does not improve on them. Figure 5 horizontal axes need labels (year). "Data" is not an acceptable y-axis labelâĂŤaren't these heads, in meters? Figure 6 is very hard to understand because the x-axes are not labeled and the y-axes are underlabeledâĂŤcount of what? Figure 7. The points are too faintâĂŤit's not clear how far the simulated heads actually fall below the measured heads. Axis labels need to include "in meters". Figure 8. These results truly show how bad this model is. Only in the deserts of the world is the depth to the water table typically greater than 100 m. Yet most of the mountain ranges here show depths greater than 300 m. There are streams in most of those mountains so we know the depth to water is zero at those locations and likely a few tens of meters at the watershed divides. If so much of the world gives results this bad it does not give me confidence in the rest of the world, and there really isn't any reason to do a model of the whole world, especially when 90% of the abstraction occurs in 10% of the area. The authors will argue that these areas don't have any significant depletion anyway, but that argues that those areas really don't need to be modeled. If the time and resources were focused on the 10% of the world where depletion was really occurring, you would get better results and might learn something. Figure 11. This figure makes no sense. If you have an areal map then depletion volumes should be represented by meters, unless what they mean is cubic kilometers per square kilometer, but given that the numbers are up to 100 that can't be the case so this figure is undecipherable. In the paper on page 11 the top sentence I see now the authors do indicate it is km3 per grid cell, but their grid cells vary in area across the globe so plotting results in this way is not consistent, nor are the number intuitive. M3/m2 would be much more meaningful. Table 1. The authors report using Sy values of 0.01 and higher for hard rocks, although in the text they way a storage coefficient of 0.001 was used for confined aquifer. Given the storage coefficient is the specific storage (which can vary by a couple of orders of magnitude) times the thickness (also quite variable) it is easy to imagine that the results could be off by a factor of ten. I realize the authors test the sensitivity by varying it by several factors, but given the authors are unable to quantify this uncertainty, it makes their results equally uncertain. Coming up with a "best-fit" scenario does not indicate their parameters are at appropriate values.

Let me summarize be saying there are three main problems I have with this paper: (1) The problem is ill posed. Most abstractions are from confined aquifers, and most water withdrawn from aquifers comes out of storage. Thus estimating the abstractions (or volumes) of withdrawal gives you one estimate (which previous authors have done) and putting those abstractions into a groundwater model does not improve on thatâĂŤit only gives you head declines. To address depletion globally focus on the regions where the impact is highest. (2) The head declines are only as good as the parameter estimates. Storage coefficients and hydraulic conductivities and thicknesses vary greatly

by magnitude and in space, so the uncertainty in the results will be high, even if you can match some head observations. The fact that in all of the mountainous terrains of the world the simulated depths to water are off by more than an order of magnitude is one warning flag. (3) Their results, in fact, didn't show anything new in terms of depletions. The locations and amounts of depletion are exactly where they told the model the pumping was, and the results were similar to past volume-based results, suggesting the water was mostly coming from storage. In their conclusions the authors state this is only one step in building a better global model, but building a model just for the sake of building it is not scientific progress. This model has an ill-posed applicationâĂŤit is not useful for learning anything new about depletions because the uncertainties are so high. It would be better suited, for example, for looking at how the water table and base flows respond to changes in climate, but it is not clear that the resolution needed for the accuracy for that application is a worthwhile endeavor at the global scale.

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